Living Wall Systems: A Technical Standard Proposal

Original
Living Wall Systems: A Technical Standard Proposal / Giordano, Roberto; Montacchini, ELENA PIERA; Tedesco, Silvia; Perone, Alessandra. - In: ENERGY PROCEDIA. - ISSN 1876-6102. - 111:(2017), pp. 298-307. [10.1016/j.egypro.2017.03.093]

Availability:
This version is available at: 11583/2672107 since: 2021-02-12T12:11:05Z

Publisher:
Elsevier Ltd

Published
DOI:10.1016/j.egypro.2017.03.093

Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 111 (2017) 298 – 307

Energy Procedia

8th International Conference on Sustainability in Energy and Buildings, SEB-16, 11-13 September 2016, Turin, ITALY

Living Wall Systems: a technical standard proposal

Roberto Giordano[a*], Elena Montacchini[a], Silvia Tedesco[a], Alessandra Perone[a]

[a]*Department of Architecture and Design, Politecnico di Torino, Turin 10125, Italy*

Abstract

Greenery is recognized as strategic element for the design and the regeneration of sustainable cities and buildings. Building integrated vegetation (BIV) offers many ecological benefits and an increasing number of local authorities, urban planners and architects are aware of these.

Living Wall Systems (LWSs) can be classified as a BIV. LWSs can be assumed as self-sufficient vertical gardens that are attached to the exterior or interior of a building. Their environmental properties are remarkable, for these cities encouraging architects to use them. Nevertheless technical standards dealing with design, construction and maintenance of LWSs are rarely available.

The objective of the research is to stimulate the LWSs development providing a technical standard proposal with information, and specifications. It tackles some aspects that should be considered significant in a standard such as: design guidelines; maintenance procedures; requirements and indicators for assessing the expected performances.

The outcome of the paper can be used a first framework to make available harmonized information to stakeholders engaged in design, off-site and on-site production, as well as in operation and repair. The standard proposal encourages innovative and responsible LWS development, with a focus on ecological requirements.

The proposal standard was implemented in consistency to an Italian standard (UNI 11235:2015). The UNI 11235 contains the instructions for designing, building up, monitoring and maintaining the green roofs. Although UNI 11235 is not an international standard it is based on a robust framework that can be applied at global scale and most importantly to LWS.

Peer-review under responsibility of KES International.

Keywords: Living Wall Sistems, technical standard; life cycle approach; design and maintenace tools.

1. Introduction

Building-integrated vegetation (BIV) are formed by green roofs and vertical greening systems applied to both exterior and internal walls. Vegetation means roofs and walls are living and breathing systems, furthermore the vegetation is encouraged to establish a strong relationship with the built structure [1].

* Corresponding author.
E-mail address: Roberto.giordano@polito.it

Peer-review under responsibility of KES International.
doi:10.1016/j.egypro.2017.03.093

While green roofs are an established technology in construction sector, recently an increasing number of stakeholders both public and private are interested in vertical greening systems. The reasons are obviously related to their unique pattern over the building envelope and over the walls but even to energy and environmental benefits described in literature [1, 2, 3].

The increasing interest about vertical greening systems refers to several benefits at urban and building scale. In addition some benefits are directly related to human well-being. The formers refer to: reduction of the Urban Heat Island effect, enhancement of urban air quality; improvement of aesthetic of boroughs; mitigation of biodiversity [2, 3], noise reduction; energy efficiency improvement; indoor Volatile Organic Compounds (VOCs) dilution; value-property increment [4, 5, 6]. The latter concern mental and physical health of citizens outside and inside the buildings [7, 3].

The literature subdivides vertical greening systems in two main systems: Green Façades and Living Wall Systems [8, 9, 10]. There is an evident distinction between green facades, where usually climbing plants grow along the wall covering it, and the most recent concepts of living walls, which include materials and technology to support a wider variety of plants, creating a uniform growth along the surface. In Living Wall Systems (LWSs) plants receive water and nutrients from within the vertical support instead of from the ground.

Despite stakeholders recognize benefits to vertical greening systems there are some obstacles for a large-scale deployment. Lack of standardization is a relevant factor that could affect the development and the dissemination of vertical greening systems and particularly of LWSs.

Throughout the countries, different programs, action plans, guidelines, etc., hereinafter presented as policies, are now available. Most of them use different criteria to assess the performances leading to incomparable results.

The main aim of the paper is to encourage the introduction of proper technical requirements with particular regard to environmental specifications to be taken into account over the LWS' life cycle.

2. Policies review

Some policies have been developed around the world to encourage green wall construction, in order to mitigate the environmental degradation and improve urban livability. Unlike other sectors, green wall adoption is not even driven by national-level policy measures, but entirely by city-level hyper local priorities. Specifically, the major types of policy drivers are financial incentives, tax rebates, technical guidelines, demonstration projects, educational programs, awards and building codes.

2.1. Extra European policies

The City of Seattle (United States) has established in 2007 the "Green Factor Program", a score system modeled on the German BAF (Biotope Area Factor, an urban planning parameter) and designed to increase the amount of green spaces in new development projects, allowing building owners to select features from a weighted menu that includes green roofs and vertical greening systems, bio-retention, tree planting or preservation, permeable paving, etc. [11].

Sidney (Australia) is committed to increasing the number of high quality green roofs and vertical greening systems, with the adoption of the "Green roofs and walls policy". This policy provides direction for Council in order to promote the use of green roofs and walls across the residential and commercial sectors [12]. A "Policy Implementation Plan" has been developed which provides specific activities and time-frames for the implementation of the policy objectives, such as: supporting sustainable design through research, guidelines and standards; collaborating with community, industry and other stakeholders; sustaining the recognition of green roofs and vertical greening systems in rating tools (e.g. LEED® Leadership in Energy and Environmental Design building certification programs); installing green roofs and vertical greening systems on Council properties [13].

Singapore (Asia) has been launched in 2009 the "Skyrise Greenery Incentive Scheme" (SGIS). The scheme finances - on existing and new buildings - up to 50% (or 500$ per square meter) of the installation cost of green roofs and vertical greening systems. Many efforts were put into research and the dissemination of skyrise greenery technologies, through: seminars, publications, awards and guidelines for designers. Since its introduction, SGIS has assisted in greening more than 110 existing buildings, with an enormous increase in greenery on high-rise projects [14].

Hong Kong government (China) has developed since 2004 strategies aimed at implementing existing and new greened areas, also through green roofs and vertical greening systems. In order to enhance the planning, design and implementation of greenery, the city started to develop “Greening Master Plans (GMPs)”. The plans are focused on suitable sites for planting vegetation with appropriate species encompassing technologies such as vertical greening systems. In 2013 the city completed 26 projects with vertical greening and green roofs for different government departments [15]. Furthermore, government has launched a community involvement projects and public education activities for several target users to foster an attitude of greening and care for the environment.

2.2. European policies

In Europe several public authorities have been encouraged the greenery use within urban and building instruments. In most cases the municipalities provide guidelines and design general strategies. Only few examples of mandatory requirements matched to financial incentives are available.

For many years Germany adopts various policies for supporting the construction of buildings with vertical greening systems. For example, the cities of Munich, Cologne, Hamburg, Düsseldorf have enacted subsidy programs or specific recommendations. Particularly, with the aim of improving the ecological situation of the existing sites in the inner city, Berlin has developed since the 1980s the BAF (Biotope Area Factor), an urban planning parameter which sets out the ratio between surfaces that have an effect on the ecosystem (e.g. vertical greening systems, green roofs, permeable surfaces, etc.) and the total site area [16]. A similar tool: the “Green Space Factor”, has been introduced in 2001 by the administration of Malmö in Sweden [17].

In the United Kingdom, the Greater London Authority recognizes that a variety of methods will be needed to tackle climate change and its consequences, and that living roofs and vertical greening systems can play a significant role in a range of environmental issues. For this reason, the Mayor of London has produced a technical guide that investigates the practical benefits of living roofs and vertical greening systems. It explores also the different barriers to their implementation. The guide points out the critical aspects that need to be considered (e.g.: localization, orientation, over-shadowing, requirements for plant, structural capability, etc.) [18].

In France, The Mayor of Paris has established new ambitious objectives for greening the city by 2020. One hundred hectares of green roofs and vertical greening systems are expected; one third of them will be dedicated to urban agriculture. In 2014 “Gardens on the walls” project has been launched involving 40 walls of building that have been vegetated. [19].

In Italy, the Law no. 10 (2014) identifies the importance of vegetation for the environment, and therefore the need to increase and to develop public and private green areas, also considering vertical greening systems [20].

In the last years, some municipalities (Firenze, Brescia, Carugate, Genova) have introduced in their building codes some guidelines aiming at promoting the use of vegetation on buildings walls, in order to reduce Urban Heat Island [21, 22, 23, 24].

Although a certain numbers of remarkable examples shows the efficiency of vertical greening systems as technology enable to improve the environmental quality of cities, borough and buildings, the policies review carried out points out a problematic issue related to the lack of an harmonized and shared international standardization. The mentioned initiatives are just limited to few administrations, they are non-mandatory and they are only referred to a generic definition of vertical greening systems. Furthermore among the guidelines mentioned none allows for the use of innovative technologies such as LWSs and - finally - economic incentives are not expected.

At least European standard eventually based on national experiences might be certainly appropriate.

3. Methodology

The aim of this research is to develop a proposal of technical standard focused on LWSs. Such focus is explained by the fact that usually a LWS allows immediately after the installation to exploit most part of energy and environmental benefits described previously [3] because the plants have already growth and as consequence the building envelope is completely covered by vegetation.

The standard proposed is the outcome of a methodological framework including international and national references.

According to European CEN/TC 350 standards - Environmental sustainability of construction works - the proposal takes into account a wider number of stages over the LWS' life cycle. CEN/TC 350 is based on a methodology aimed at achieving a transparent description of environmental performances of construction works within a life cycle approach. The assessment can be used for comparing solutions or choices involving different materials and building systems. Consistent with these principles the research analyzed the following stages of a LWS' life cycle:

- Design
- Manufacturing
- On-site assembling
- Maintenance

Some aspects related to end-of-life stage were even considered although the information available are still very poor now. This is probably due to the fact that LWSs are recent systems for the construction sector and very few of them were dismantled.

An Italian technical standard concerning the green roof was adopted as further methodological reference: UNI 11235:2015. At present it can be considered as a comprehensive and detailed standard providing technical specifications regarding: design, construction and maintenance of green roofs [25]. Obviously the standard proposal hereafter specified introduces supplementary technical specifications according to LWSs features.

On the whole the following analysis were carried out:

- Analysis of selected international guidelines
- Analysis of LWSs technological solutions
- Analysis of stakeholders needs

3.1. Analysis of selected international guidelines

Within the above-mentioned policies just a few include a plurality of information about the vertical greening systems over their life cycle mainly through guidelines for designers and building technicians.

With regards to CEN/TC350 only four guidelines give a detailed set of information about life cycle stages: 1) the Growing Green Guide (Melbourne – Australia) [26], 2) the short-guide to safe practices for vertical greenery (Singapore , Republic of Singapore) [27]; 3) the Végétalisation des murs et des toits (Paris, France) [28], 3) the UK Guide to Green Walls (United Kingdom) [29].

The comparison among them was carried out encompassing the following key-topics: benefits; typologies; design; installation; maintenance; plant selection. Such topics were assumed because of their relatively frequent occurrence in worldwide policies analyzed in the par. 2.

The analysis carried out shows the guidelines take into account mostly information about the on-site and operational stage while information about manufacturing and end-of-life are rather poor.

3.2. Analysis of LWSs technological solutions

An analysis concerning LWSs technological solutions was carried out. It was based both on a literature review and taking into account several LWSs available on the building market.

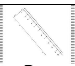
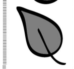
The study was preparatory for laying down the LWSs typologies to be included in the proposal of technical standard. It was based on criteria such as lightweight vs heavyweight or indoor vs outdoor uses, etc.

In order to make possible a comparison among LWSs a datasheet was developed to collect a wide range of information. The datasheet was divided in two parts. The first one includes the technical and performance data, providing information about technological characteristics, materials and products performances. Table 1 displays the technical data collected.

The second one contains general information related to architectural design solutions, executive drawings and pictures taken from selected buildings, useful for a better understanding of formal and morphological aspects.

On the whole the total number of filled datasheets reached 40.

Table 1. Technical data collected in the analysis carried out on LWSs

Data		Description	Unit
Sizing		The data refers to the green wall technological system, in particular to the plant structures	cm
Weighting		The data refers to the dry weight and to the saturation weight of an individual modular LWS	Kg/m^2
Water consumption		The data refers to the average annual water consumption	l
Plants per square meter		The data refers to the number of plants placed in the LWS per square meter	N.
Type of substrate		The data refers to the substrate characteristics, essential for the choice of plant species	n.a.

3.3. Analysis of stakeholders needs

The primary intent of this study was to provide useful information to be included in the technical standard proposal gathered from semi-structured interviews over a purposive sample of 31 subjects identified as the main practitioners in the fields of LWS design and construction (response rate 100%).

The data was collected with non-probabilistic sampling techniques and analyzed using qualitative research techniques consistently to previous literature studies [30, 31].

In selecting the interviewees the following criteria were used:

- Architects/landscape architects interested vertical greening systems and in particular in LWSs (n. 15)
- Agronomists experienced in greenery into urban environment (n. 6)
- Companies leader in LWS manufacturing (n. 3)
- Academics and researchers involved in LWSs studies as well as in training and dissemination campaigns (n. 7)

The semi-structured interviews were guided by a set of topics and open-ended questions prepared beforehand, with the discussion taking place during the interview. The framework for the interviews concerns the issues related to strengths and weaknesses of LWS technology. Interviewees were given the opportunity to discuss their opinion on questions regarding:

- Reasons for using (or eventually not using) the LWS in a building project (architects)
- Aspects related to operational stage (agronomists)
- Factors influencing the LWSs cost as well as market barriers for a LWSs dissemination (manufacturers)
- Requirements of LWS to be included for a sustainable building design (academics and researchers)
- Utility of a future regulation concerning LWSs (all)

The findings show that for architects the energy and environmental benefits are the main reasons for using LWSs despite the initial costs are assumed as very high. Although the information heterogeneity makes extremely difficult a comparison among systems. The maintenance processes and matched costs are important factors that affecting the decision to install (or not) a LWS. For architects basic information about maintenance should be always provided after the installation.

For agronomists the plant species must be carefully selected depending on: the microclimatic conditions, the LWS features (extremely important is considered the growing medium) and the building orientation. The technological integration of the irrigation system play a crucial role for a LWS long life. For agronomists irrigation system requires to be frequently checked (at least twice times a year).

Manufactures point out that the relatively high costs of LWSs are mainly due human resources necessary for the manufacturing processes. The many manual operations required influence the LWSs cost. Raw materials and semi-finished products used in the off-site production are less significant despite not negligible. A future higher industrialization of systems would lead to costs reduction.

They even recognized a market barrier due to a lack of requirements to fulfill similarly to those included in Regulation EU 305/11 laying down harmonized conditions for the marketing of construction products.

Finally academics say that despite the state-of-the-art shows ecological and energy benefits such benefits are often tackled separately, they are referred to particular climates and they are studied with different accuracy levels. A reference list of ecological requirements should be helpful.

On the whole all the stakeholders agree upon the utility of a standard that encompasses the aspects surveyed during the interviews.

4. Results

The intended use of the standard proposal is to provide technical information to stakeholders concerning the LWSs. Users of the standard are: planners, developers, architects, landscape architects, engineers, general contractors, subcontractors, owners, facility managers, financial organizations related to building industry, building materials and product manufacturers, public authorities, and other building technicians.

The standard proposal is divided into 8 paragraphs regarding the following areas:

- Significance and Use
- Scope
- Definitions
- Ecological requirements
- Project and design
- Construction and monitoring
- Maintenance
- References

A selection of the main paragraphs are illustrated and discussed below, in particular: scope; ecological requirements; project and design; maintenance.

4.1. Scope

The scope of standard proposal was laid down according to analysis on technological systems available (par. 3.2). The following LWSs are the subject of standardization:

- Continuous systems. They are based on the application of lightweight and permeable fabrics in which plants are inserted individually
- Modular systems. They are based on elements with specific dimension, they include the growing media where plants can grow
- Lightweight systems. LWS - saturated with water – with: weight $P<80$ kg/m^2; substrate thickness <15 cm
- Heavy systems. LWS - saturated with water – with: weight $P>80$ kg/m^2; substrate thickness ≥15 cm

Furthermore the paragraph introduces technical specifications concerning:

- Indoor LWSs placed in controlled environment [20-22 °C] over the year. They are similar in all the geographical areas
- Outdoor LWSs subjects to the climate and microclimate. They can be threatened by environmental variations.

4.2. Ecological requirements

The standard proposal sets out the ecological requirements needed to be fulfilled with regards to the life cycle of a LWS. Requirements were listed on the basis of the analysis carried out (see par 3.1, par. 3.2 and par. 3.3).

On the whole 40 requirements were identified: 12 related with manufacturing stage, 4 with on site assembling stage, 18 with use and maintenance stages, 6 with final disposal.

Such requirements were gathered, classified and arranged in a tabular format: fiche. Each fiche refers to a requirement, it includes: the life cycle stage (e.g. manufacturing, maintenance, etc.), the category impact (e.g. non-renewable source depletion, carbon dioxide emissions, etc.), the corresponding requirement (e.g. maximizing the use of low environmental impact materials, minimizing the water need and giving priority to organic fertilizer) and the indicator (qualitative or quantitative), and finally, the assessment method for the requirement characterization (Fig. 1). The indicator and the assessment method allow the comparison among different LWSs solutions.

Overall the fiches can be considered as a technical specification of the standard proposal.

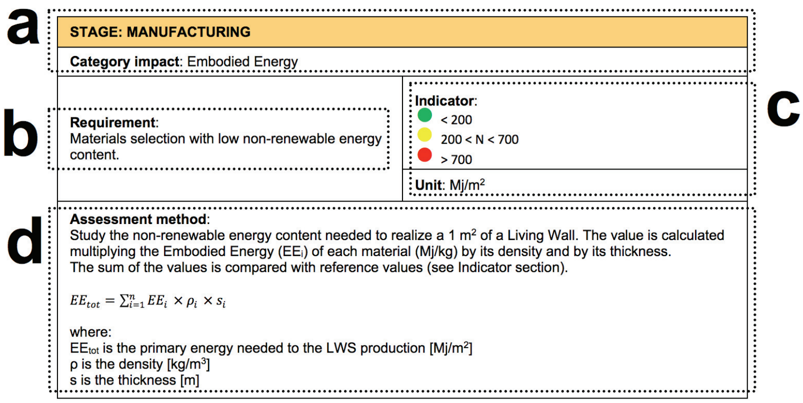


Fig. 1. Example of technical fiche: (a) life cycle stage and category impact; (b) requirement; (c) indicator; (d) assessment method for the requirement characterization.

4.3. Project and design

The project and design paragraph was based on the analysis of selected guidelines (par 3.1) and from the findings of the analysis of stakeholder needs (par. 3.3).

Details concerning LWSs were illustrated. Every detail refers to: 1) conventional LWSs layers (e.g. main framework, roots anchorage, growing medium, permeable sheet, etc.); 2) LWSs generic connections to other building systems (e.g. connection to window, roof etc); 3) standard systems for irrigation-water reuse.

Guidelines for a proper LWS design were also integrated. With particular reference on vegetative layer the technical standard proposal includes an agronomic database of plants suitable for LWS. The database was thought as technical specification or an annex. In particular a list of species fit for indoor purpose are recorded.

The agronomic database was divided in: Part 1: botanical and ecological data; Part 2: hygro-thermal and comfort data. The former provides botanical data (e.g. species name, group and family, height, type, habit, leaf, root system) and ecological data (e.g. conditions of growth, watering, lighting, maintenance). The latter gives information on comfort requirements through a superimposition on bioclimatic chart of plant needs on bioclimatic chart of human needs. Such analysis was allowed to assess the plants effectiveness use with specific indoor conditions and their correlation with human comfort zone. It was carried out by the adoption of Olgyay chart with regards to a range of climatic variables. Olgyay's bioclimatic chart specify different zones at different combinations of relative humidity and dry bulb temperatures; the level of comfort is applicable to indoor spaces according to a indoor level of clothing.

The human comfort zone is featured to a range of variables including indoor air temperature, relative humidity, solar radiation absorbed and internal air movement as well. According to human requirements the green area (see Fig. 2) outlines the best comfort zone.

Indoor air temperature and relative humidity were assumed as variables for plants comfort (see Fig. 2 – yellow area). On the whole 28 plants were analyzed and assessed as suitable for indoor uses and compatible in terms of comfort needs [32].

Figure 2 displays an example of plant specie analyzed (Scindapsus). The percentage of compatibility (see Fig. 2 – dotted line area) was obtained by dividing the human comfort zone by the plant comfort zone. Percentage calculated for Scindapsus was 54%. Such value was assumed as “good compatibility”. Thirty-five percent was the limit value assumed as acceptable for considering the zones as each other compatible.

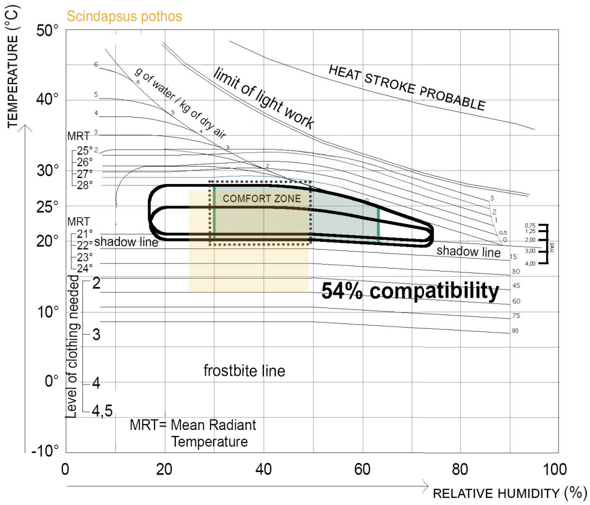


Fig. 2. Olgyay’s chart: superimposition between the human comfort zone and the Scindapsus (plant specie) one. The dotted line area shows the compatibility between the analyzed zones

4.4. Maintenance

The maintenance paragraph was related mainly on the interviews carried out (par. 3.3). As mentioned the lack of information about plants care, upkeeps of LWS’ layers, etc. is a critical issue. In order to boosting the use of LWSs a proposal section deals with the procedures to be consider during the operation of LWSs.

Maintenance procedures are considered as “routine” and “special”. Routine maintenance provides for the following processes: irrigation equipment check; vegetation growth monitoring; number of pruning planned per year; in-service control of materials and components. Special maintenance provides for the subsequent processes: irrigation system repair; material and components repair and replacement; anti-parasitic treatments.

Routine maintenance can be furthermore organized through two main levels according to plants care frequency:

- Average frequency: less than or equal to two maintenance processes per year
- High frequency: more than two maintenance processes per year

The frequency needed to be set out in design stage. Thus the operational costs are taken into account leading to an economic sustainability assessment.

The proposal recommends still in this stage to provide a maintenance manual. Manufacturers are responsible for drawing up the manual. The instructions provided take into consideration the following activities: 1) regular checks;

2) Plants checks and vegetation growth monitoring; 3) irrigation equipment check; 4) dosing and irrigation programming.

5. Discussion

The standard proposal is based upon a methodology which takes into accounts the LWS over its life cycle, according to current environmental principles. It refers to similar Italian standard implemented for green roof, thus to guarantee a consistency within the BIV in terms of technical and ecological requirements. It is developed to optimize and to compare the technological systems currently available on the market. Furthermore it encourages innovative and responsible LWS implementation both outdoor and indoor. Finally the key issues analyzed are the outcomes of the involvement of the main categories of practitioners in order to lay the foundation for an interdisciplinary and shared approach.

The standard can be assumed in its initial elaboration. In the upcoming it will be submitted to Italian Organization for Standardization (UNI) for a preliminary evaluation.

The future work shall provide for a development of technical specifications as described in the paper. Particularly the technical specification concerning the ecological requirements entails to characterize physical indicators based on the scientific state-of-the-art, such as: dynamic U-value; surface temperature; embodied energy and carbon, sound absorption coefficient, etc.

The technical specification concerning the agronomic database will be implemented too. New plant species will be extended, including for instance the aromatic herbs and the vegetables.

A reference standard could lead to a wider recognition in public procurement and in private investments. It would be good considering a LWS as usual building system.

LWSs needed to be recognized as energy efficiency and environmentally friendly technological systems. Such connotation would result an improvement in market access and tax benefits.

6. Conclusion

The paper highlights the key role that might play a technical standard focused on LWSs to improve the features of products and to encourage their use.

LWSs - within the BIVs - are self-sufficient vertical gardens attached to walls and partitioning. They combine a unique design with a high number of ecological benefits. Although the increasing interest about these systems LWS' standards are rarely available.

The paper deals with some aspects considered as noteworthy for a standard development (i.e. design guidelines; maintenance procedures; requirements and indicators for assessing the expected performances).

The outcome of the paper can be used a first framework to make available harmonized information to stakeholders engaged in design, off-site and on-site production, as well as in operation and repair.

7. Acknowledgments

The authors' wish thanks Growing Green srl for its support in the analysis carried out for the consultancy services.

A special thanks goes to professor Federica Larcher for the agronomic advices and to architect Massimiliano Consolandi for the precious help in collecting data for drawing up the technical specifications.

References

[1] Grant G. Green roofs and façades. Berkshire (UK):HIS BRE Press; 2006.

[2] Candelari E, Giordano R, Serra V. Vertical Greening Systems and Urban Heat Island related aspects: outcomes of a research project. Proceeding of the 3rd International Conference on Countermeasures to Urban Heat Island, Venice (I); 2014.

[3] Weinmaster M. Are green walls as 'green' as they look? An Introduction to the various technologies and ecological benefits of green walls.

Journal of Green Building 2009; 4: 3-18.
[4] Raji B, et al. The impact of greening systems on building energy performance: A literature review. Renew Sust Energ Rev 2015; 45:610-623.
[5] Azkorra Z, et al. Evaluation of green walls as a passive acoustic insulation system for buildings. Appl Acoust 2015; 89: 46-56.
[6] Rosasco P, Perini K. Verifica di sostenibilità economica per sistemi di facciate verdi. Valori e Valutazioni 2014; 13: 67-93.
[7] Burchett M, et al. Greening the Great Indoors for Human Health and Wellbeing, Final Report to Horticolture Australia Ltd 2010. <www.ngia.com.au/Story?Action=View&Story_id=1897> [Accessed 03/2016].
[8] Kohler M. Green facades – a view back and some visions. Urban Ecosyst 2008; 11:423–436.
[9] Dunnett N, Kingsbury N. Planting green roofs and living walls. Portland/London: Timber Press; 2008.
[10] Manso M, Castro-Gomes J. Green wall systems: a review of their characteristics. Renew Sust Energ Rev 2015; 41: 863 - 871.
[11] Hirst J, Morley J, Bang K. Functional Landscapes: Assessing Elements of Seattle Green Factor 2008. <http://www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/dpds021359.pdf> [Accessed 03/2016].
[12] City of Sydney. Green Roofs and Walls Policy. Sydney; 2014. <http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0011/200243/2014_126384__policy__green_roofs_and_walls2.pdf> [Accessed 03/2016].
[13] City of Sydney. Green Roofs and Walls Policy Implementation Plan. Sydney; 2014. <http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0010/200242/Green-Roofs-and-Walls-Policy-Implementation-Plan-Adopted>. [Accessed 03/2016].
[14] Skyrise Greenery - Incentive Scheme SGIS. Republic of Singapore <https://www.skyrisegreenery.com/index.php/home/incentive_scheme/about/ > [Accessed 03/2016].
[15] Greening Hong Kong. Hong Kong Government. March 2016. <http://www.gov.hk/en/residents/environment/sustainable/greening.htm> [Accessed 03/2016]
[16] BAF – Biotope Area Factor. Berlin.de. Senate Department for Urban Development and the Environment. <http://www.stadtentwicklung.berlin.de/umwelt/landschaftsplanung/bff/index_en.shtml> [Accessed 03/2016].
[17] The Green City. Malmö stad. <http://malmo.se/English/Sustainable-City-Development-2016/Sustainable-City-Development/Bo01---Western-Harbour/Green-City.html> [Accessed 03/2016].
[18] Mayor of London. Living Roofs and Walls. Technical Report: Supporting London Plan Policy. London; 2008. <https://www.london.gov.uk/what-we-do/planning/london-plan/london-plan-technical-and-research-reports > [Accessed 03/2016].
[19] Mairie de Paris; 2015. <http://next.paris.fr/english/english/over-21-000-parisians-back-gardens-on-the-walls-project/rub_8118_actu_155139_port_19237> [Accessed 03/2016].
[20] Legge n. 10 del 14 Gennaio 2013. Norme per lo sviluppo degli spazi verdi urbani.
[21] Regolamento edilizio del Comune di Firenze, 2005.
[22] Regolamento edilizio del Comune di Brescia, 2007.
[23] Regolamento edilizio del Comune di Carugate, 2008.
[24] Regolamento edilizio del Comune di Genova, 2010.
[25] UNI 11235:2015. Istruzioni per la progettazione, l'esecuzione, il controllo e la manutenzione di coperture verdi.
[26] State of Victoria, the Inner Melbourne Action Plan, University of Melbourne. Growing Green Guide: A guide to green roofs, walls and facades in Melbourne and Victoria. 2014. <http://www.growinggreenguide.org/wpcontent/uploads/2014/02/growing_green_guide_ebook_130214.pdf> [Accessed 03/2016].
[27] National Parks Board. A concise guide to safe practices for vertical greenery. 2013. <https://www.skyrisegreenery.com/images/uploads/publications/A_Concise_Guide_to_Safe_Practices_for_Vertical_Greenery.pdf> [Accessed 03/2016].
[28] Mairie de Paris. Végétalisation des murs et des toits. 2014. <http://api-site-cdn.paris.fr/images/71023> [Accessed 03/2016].
[29] Urban Greening. UK Guide to Green Walls. An introductory guide to designing and constructing green walls in the UK 2013. <http://media.wix.com/ugd/c0a820_877fc4a9e779472c53296c58fdfb8d20.pdf > [Accessed 03/2016].
[30] Bartczak C. Living walls in the built environment. <http://www.bus.umich.edu/Conferences/ConstructingGreen-AnnArbor2010/GetFile.aspx?paper_ord=2289> [Accessed 03/2016]. .
[31] Knowles L., et al. Living Wall. A feasibility study for the SLC. <http://environment.uwaterloo.ca/research/watgreen/projects/library/f02livingwall.pdf> [Accessed 03/2016].
[32] Giordano R, Montacchini E, Tedesco S. Indoor performances of living wall systems: tools and requirements. Proceedings of International Conference CISBAT, 9-11 September Lausanne. 2015.